



MARKSCHEME

November 2009

CHEMISTRY

Higher Level

Paper 2

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General Marking Instructions

Assistant Examiners (AEs) will be contacted by their team leader (TL) by e-mail (or telephone) – if by e-mail, please reply to confirm that you have downloaded the markscheme from IBIS. The purpose of this initial contact is to allow AEs to raise any queries they have regarding the markscheme and its interpretation. AEs should contact their team leader by e-mail at any time if they have any problems/queries during the marking process.

Note:

The DHL courier service must be used to send assessment material to your team leader/senior moderator and to IB Cardiff. (However, this service is not available in every country.) The cost is met directly by the IBO. It is vitally important that the correct DHL account number is used.

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1. Follow the markscheme provided, award only whole marks and mark only in **RED**.
2. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**
3. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases write a brief annotation to explain your decision. You are encouraged to write comments where it helps clarity, especially for moderation and re-marking. It should be remembered that the script may be returned to the candidate.
4. Unexplained symbols or personal codes/notations are unacceptable.
5. Record marks in the right-hand margin, against each mark allocation shown in square brackets *e.g.* [2]. The total mark for a question must equal the number of ticks for the question.
6. Do **not** circle sub-totals. **Circle the total mark** for the question in the right-hand margin **at the end of the question.**
7. Where an answer to a part question is worth no marks, put a zero in the right-hand margin next to the square bracket.
8. Where work is submitted on additional sheets the marks awarded should be shown as ticks and a note made to show that these marks have been transferred to the appropriate square bracket in the body of the script.
9. For each option: Add the totals for each question in the option and write it in the Examiner column on the front cover.
Total: Add the marks awarded and enter this in the box marked TOTAL in the Examiner column on the cover sheet.
10. After entering the marks on the front cover check your addition to ensure that you have not made an error. Check also that you have transferred the marks correctly to the cover sheet. **All scripts are checked and a note of all clerical errors will be given in feedback to examiners.**
11. If an answer extends over more than one page and no marks have been awarded on a section draw a diagonal line through that section to indicate that it has been marked.
12. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers and use the marks of those answers that have the highest mark, **unless the candidate has indicated the question(s) to be marked on the front cover.**
13. A mark should not be awarded where there is contradiction within an answer. Make a comment to this effect in the left hand margin.

Subject Details: Chemistry HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A [**40 marks**] and **TWO** questions in Section B [**2 × 25 marks**]. Maximum total = [**90 marks**].

1. A markscheme often has more marking points than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.
2. Each marking point has a separate line and the end is signified by means of a semicolon (;).
3. An alternative answer or wording is indicated in the markscheme by a slash (/) – either wording can be accepted.
4. Words in brackets () in the markscheme are not necessary to gain the mark.
5. Words that are underlined are essential for the mark.
6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.
7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing **OWTTE** (or words to that effect).
8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. Indicate this with **ECF** (error carried forward).
10. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover page.
11. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

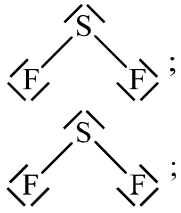
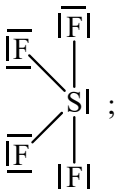
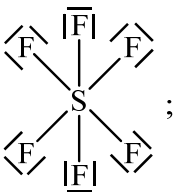
2	<i>reject</i>
1.6	accept
1.63	accept
1.631	accept
1.6314	<i>reject</i>

Indicate the mark deduction by writing **–1(SD)** at the first point it occurs and **SD** on the cover sheet.

12. If a question specifically asks for the name of a substance, do not award a mark for a correct formula, similarly, if the formula is specifically asked for, do not award a mark for a correct name.
13. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the markscheme.
14. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

SECTION A

1. (a) $\text{MnO}_4^- (\text{aq}) + 5\text{Fe}^{2+} (\text{aq}) + 8\text{H}^+ (\text{aq}) \rightarrow \text{Mn}^{2+} (\text{aq}) + 5\text{Fe}^{3+} (\text{aq}) + 4\text{H}_2\text{O} (\text{l})$ **[2]**
Award [2] if correctly balanced.
Award [1] for correctly placing H^+ and H_2O .
Award [1 max] for correct balanced equation but with electrons shown.
Ignore state symbols.
- (b) Fe^{2+} / iron(II); **[1]**
Do not accept iron.
- (c) $n = 2.152 \times 10^{-2} \times 2.250 \times 10^{-2}$;
 $4.842 \times 10^{-4} (\text{mol})$; **[2]**
Award [1] for correct volume
Award [1] for correct calculation.
- (d) 1 mol of MnO_4^- reacts with 5 mol of Fe^{2+} ;
 $5 \times 4.842 \times 10^{-4} = 2.421 \times 10^{-3} (\text{mol})$; **[2]**
 (same number of moles of Fe in the iron ore)
Allow ECF from part (a) and (c) provided some mention of mole ratio is stated.
- (e) $2.421 \times 10^{-3} \times 55.85 = 0.1352 (\text{g})$;
 $\frac{0.1352}{0.3682} \times 100 = 36.72\%$; **[2]**
Allow ECF from part (d).

	SF ₂	SF ₄	SF ₆	
Lewis structure	 <i>2 lone pairs on S required for the mark</i>	 <i>1 lone pair on S required for the mark</i>		
Name of shape	bent/angular/V shaped;	Seesaw/distorted tetrahedral;	octahedral; <i>Accept square bipyrimidal</i>	[6]

Penalise missing lone pairs on fluorine atoms once in correct structures only.

For Lewis structures candidates are not expected to draw exact shapes of molecules.

Do not allow ECF for wrong Lewis structures.

Accept dots or crosses instead of lines.

3. (a) series of lines/lines;
 electron transfer/transition between higher energy level to lower energy level /
 electron transitions into first energy level causes UV series / transition into second
 energy level causes visible series / transition into third energy level causes
 infrared series;
 convergence at higher frequency/energy/short wavelength; [3]
Allow any of the above points to be shown on a diagram.
- (b) [Fe(CN)₆]⁴⁻ = +2;
 [FeCl₄]⁻ = +3; [2]
Award [1 max] if 2+ and 3+, 2 and 3 or II and III stated.

4. (a) electrolytic cell converts electrical energy to chemical energy **and** voltaic cell converts chemical energy to electrical energy / electrolytic cell uses electricity to carry out a (redox) chemical reaction **and** voltaic cell uses a (redox) chemical reaction to produce electricity / electrolytic cell requires a power supply **and** voltaic cell does not;

electrolytic cell involves a non-spontaneous (redox) reaction **and** voltaic cell involves a spontaneous (redox) reaction;

in an electrolytic cell, cathode is negative and anode is positive **and** *vice-versa* for a voltaic cell / electrolytic cell, anode is positive and voltaic cell, anode is negative / electrolytic cell, cathode is negative and voltaic cell, cathode is positive;

voltaic cell has two separate solutions **and** electrolytic cell has one solution / voltaic cell has salt bridge and electrolytic cell has no salt bridge;

electrolytic cell, oxidation occurs at the positive electrode/anode **and** voltaic cell, oxidation occurs at the negative electrode/anode/*vice-versa*; [2 max]

If descriptions are reversed for electrolytic and voltaic cell, penalize first marking point but award second marking point as ECF.

- (b) (i) $2\text{Al(s)} + 3\text{Ni}^{2+}(\text{aq}) \rightarrow 2\text{Al}^{3+}(\text{aq}) + 3\text{Ni(s)}$; [2]

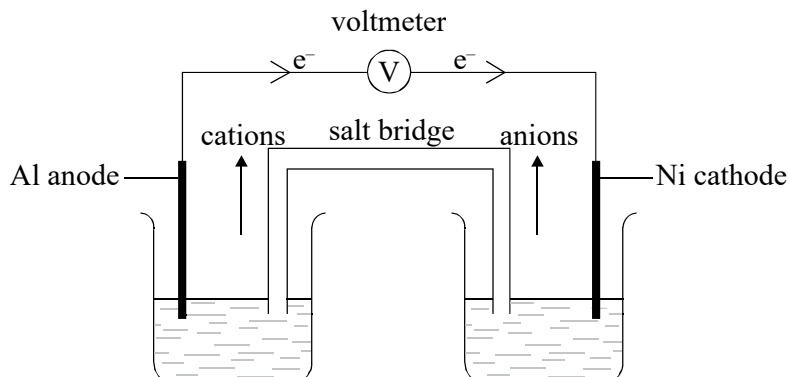
Correct reactants and products, award [1]

Balancing award [1].

Ignore state symbols and equilibrium sign.

- (ii) (+) 1.40 (V); [1]

- (iii) aluminium anode/negative electrode;
nickel cathode/positive electrode;
electron movement from Al to Ni;
correct movement of cations and anions through salt bridge; [4]
If electron movement shown correctly but not labelled, award the mark



5. (a) (i)

Isomer	A	B	C
Boiling point	36 °C	28 °C	10 °C

Award [1] if correct boiling points are assigned to 3 isomers.

increase in branching / more side chains / more spherical shape
 reduced surface contact / less closely packed;
 weaker intermolecular force/van der Waals'/London/dispersion forces;
Accept the opposite arguments

[3]

(ii) B: 2-methylbutane/methylbutane;
 C: 2,2-dimethyl propane/dimethyl propane;
Do not penalize missing commas, hyphens or added spaces.
Do not accept 2-dimethylpropane or 2,2-methylpropane.

[2]

(b) C_5H_{12} ;

Accept any two of the following explanations.

$C_5H_{11}OH$ has greater molar mass / produces less grams of CO_2 and H_2O per gram of the compound / suitable calculations to show this;
 $C_5H_{11}OH$ contains an O atom which contributes nothing to the energy released / partially oxidized / *OWTTE*;
 analogous compounds such as butane and butan-1-ol show a lower value for the alcohol per mole in the data book / *OWTTE*;
 the total bond strength in the pentanol molecule is higher than the total bond strength in pentane;
 the total amount of energy produced in bond formation of the products per mole is the same;
 fewer moles of pentanol in 1 g;
 pentanol requires more energy to break intermolecular forces / H bonding / *OWTTE*; [3 max]

(c) *Improvements [2]*

less/no particulates/C/CO/VOC's produced with CNG;
 less/no SO_2/SO_x produced;

Reasons [1 max]

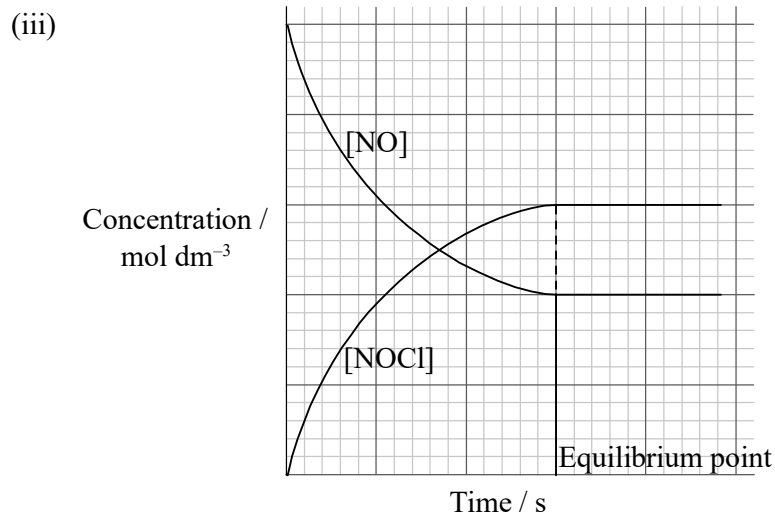
CO/ SO_2 toxic/poisonous;
 SO_2 causes acid rain;
 CNG is likely to undergo complete/more combustion;
 CNG has no/less sulfur impurities;

[3 max]

SECTION B

6. (a) (i) $\text{rate} = k[\text{NO}]^2[\text{Cl}_2]$; [1]

(ii) rate of reaction will decrease by a factor of 4;
no effect on the rate constant; [2]



y axis labelled concentration/mol dm⁻³ and x axis is labelled time/s;
gradient for [NO];
gradient for [NOCl] will be equal and opposite;
equilibrium point identified / two curves level off at same time; [4]

(b) Above 775 K: $\text{rate} = k[\text{NO}_2][\text{CO}]$;
Below 775 K: $\text{rate} = k[\text{NO}_2]^2$; [2]

(c) zero order reaction;
all concentrations are 1.0 mol dm⁻³; [2]

(d) $\text{slope} = \frac{9.2 - 8.4}{(3.53 - 3.65) \times 10^{-3}} = -6.67 \times 10^3$;
($E_a = 6.67 \times 10^3 \times 8.31$)
55.4 (kJ mol⁻¹); [2]
Accept in range 55.0 – 56.0
Award [1] if 55454 (J) stated
Award [2] for the correct final answer

(e) (i) $(K_c) = \frac{[\text{SO}_2\text{Cl}_2]}{[\text{Cl}_2][\text{SO}_2]}$; [1]

Ignore state symbols.

Square brackets [] required for the equilibrium expression.

- (ii) 7.84×10^{-3} mol of SO_2 and 7.84×10^{-3} mol of Cl_2 ;
 7.84×10^{-3} mol dm⁻³ of SO_2 , 7.84×10^{-3} mol dm⁻³ of Cl_2 **and**
 7.65×10^{-4} mol dm⁻³ of SO_2Cl_2 ;
 12.5;

[3]

Award [1] for 10.34

Award [3] for the correct final answer

- (iii) value of K_c increases;
 $[\text{SO}_2\text{Cl}_2]$ increases;
 decrease in temperature favours (forward) reaction which is exothermic;
Do not allow ECF.

[3]

- (iv) no effect on the value of K_c / depends only on temperature;
 $[\text{SO}_2\text{Cl}_2]$ decreases;
 increase in volume favours the reverse reaction which has more gaseous moles;
Do not allow ECF.

[3]

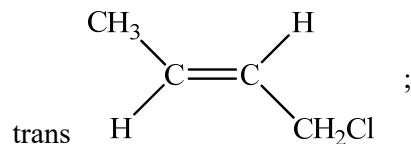
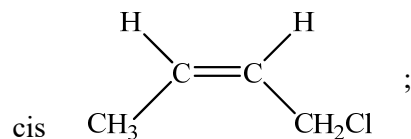
- (v) no effect;
 catalyst increases the rate of forward and reverse reactions (equally) / catalyst
 decreases activation energies (equally);

[2]

7. (a) (i) **A:** sublimation/atomization;
B: atomization/half dissociation enthalpy;
D: (sum of 1st and 2nd) electron affinity; [3]
Do not accept vaporization for A and B.
Accept ΔH_{AT} or ΔH_{EA} .
- (ii) enthalpy change when one mole of the compound is formed from its elements
 (in their standard states);
 under standard conditions / 25 °C/298 K **and** 1 atm/101.3 kPa/1.01 × 10⁵ Pa; [2]
- (iii) $-602 = 150 + 248 + 2186 + 702 + E$;
 $-3888 \text{ (kJ mol}^{-1}\text{)}$; [2]
Do not allow 3889 (given in data booklet).
Allow 3888 (i.e no minus sign).
Award [2] for the correct final answer.
- (iv) energy required to remove one electron;
 from an atom in its gaseous state;
 electron removed from a positive ion;
 decrease in electron-electron repulsion / increase in nucleus-electron attraction; [4]
- (v) MgO;
 double ionic charge / both ions carry +2 and –2 charge/greater charge compared
 to +1 and –1; [2]
- (b) (i) $\text{C}_2\text{H}_6(\text{g}) + 3\frac{1}{2}\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$ $\Delta H^\ominus = -1560$;
 $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g})$ $\Delta H^\ominus = +286$;
 $2\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_2\text{H}_4(\text{g}) + 3\text{O}_2(\text{g})$ $\Delta H^\ominus = +1411$;
 $\text{C}_2\text{H}_6(\text{g}) \rightarrow \text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g})$ $\Delta H^\ominus = +137 \text{ (kJ)}$; [4]
Allow other correct methods.
Award [2] for –137.
Allow ECF for the final marking point.
- (ii) positive;
 increase in number of moles of gas; [2]
- (iii) at low temperature, ΔH^\ominus is positive **and** ΔG is positive;
 at high temperature, factor $T\Delta S^\ominus$ predominates **and** ΔG is negative; [2]
- (iv) Bonds broken (1C–C, 6C–H, or 1C–C, 2C–H) = 2825/1173;
 Bonds made (1C=C, 1H–H, 4C–H) = 2700/1048;
 +125 (kJ); [3]
Allow 125 but not –125 (kJ) for the final mark.
Award [3] for the correct final answer.
- (v) bond enthalpy values are average values; [1]

8. (a) (i) 9.5; [1]
Accept any value in the range 9.4–9.6.
- (ii) titration involves a weak acid **and** a strong base;
 salt formed at equivalence point is basic due to hydrolysis;
 $A^-(aq) + H_2O(l) \rightleftharpoons HA(aq) + OH^-(aq)$; [3]
Ignore state symbols.
- (iii) $\frac{0.155 \times 22.0 \times 1}{25.0 \times 1}$;
 $= 0.136 (\text{mol dm}^{-3})$; [2]
- (iv) at half neutralization point, $pH = pK_a$;
 $pK_a = 5.3$;
Accept any value in the range 5.2–5.4.
 $K_a = 5.0 \times 10^{-6} (\text{mol dm}^{-3})$; [3]
Accept calculations based on initial pH or on pH of salt.
- (v) phenolphthalein; [1]
Accept thymolphthalein.
Allow ECF from (a)(i).
- (b) $HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$;
 colour A colour B
 in presence of acid/ H^+ , equilibrium shifts to left, colour A;
 in presence of base/ OH^- , equilibrium shifts to right, colour B; [3]
- (c) (i) buffer solution resists change in pH;
 on addition of small amount of acid or base; [2]
- (ii) after mixing $[CH_3COO^-] = [CH_3COOH] = 0.050 \text{ mol dm}^{-3}$;
 $K_a = [H^+] / pK_a = pH$;
 $pH = 4.76$; [3]
Working must be shown to score [3].
Award [1] if 4.76 stated with no working.
- (d) acidic;
 $[Al(H_2O)_6]^{3+}(aq) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H^+(aq)$; [2]
Accept $AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$.
- (e) (i) $[H^+] = \frac{1.00 \times 10^{-14}}{1.28 \times 10^{-3}} = 7.81 \times 10^{-12} \text{ mol dm}^{-3}$ / $pOH = -\log 1.28 \times 10^{-3} = 2.90$;
 $pH = (14.0 - 2.90) = 11.1$; [2]
Award [2] for the correct final answer
- (ii) $K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$;
 $= \frac{(1.28 \times 10^{-3})^2}{0.100 - 0.00128} / \frac{(1.28 \times 10^{-3})^2}{0.100}$;
 $= 1.66 \times 10^{-5} / 1.64 \times 10^{-5}$; [3]

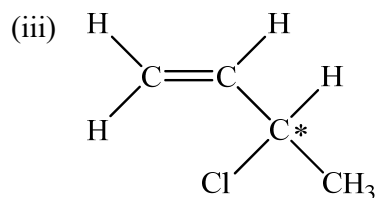
9. (a) (i)



[2]

(ii) no rotation possible due to double bond/pi bond;
Accept hindered or restricted rotation.

[1]



correct structural formula;
chiral carbon atom identified;

[2]

(b) (i) trans has the higher melting point;
trans isomer has (predominantly) intermolecular hydrogen bonding;
cis isomer has (predominantly) intramolecular hydrogen bonding;

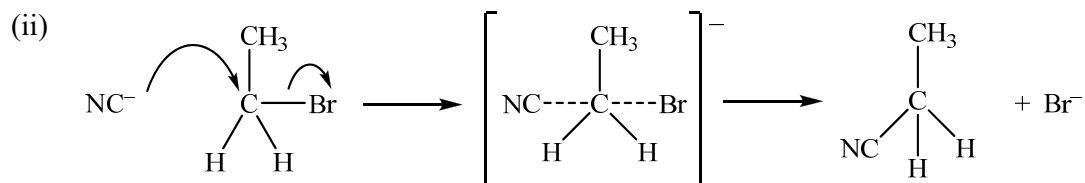
[3]

(ii) cis isomer readily releases water (vapour forming a cyclic anhydride);
Accept opposite arguments for trans isomer.

[1]

(c) (i) S_N2 ;

[1]



curly arrow going from CN^- to C;
curly arrow showing Br leaving;
Curly arrow may be represented on transition state.

representation of transition state, showing negative charge and dotted lines;
products;

[4]

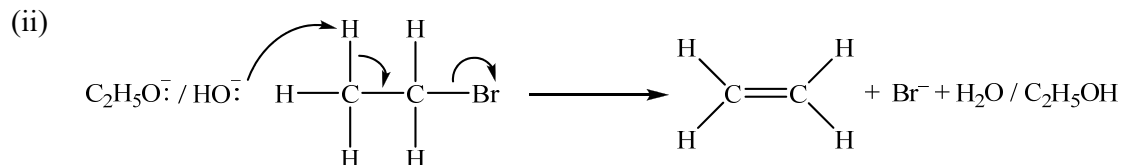
(iii) $CH_3CH_2CN + 2H_2 \rightarrow CH_3CH_2CH_2NH_2$;
Ni / Pt / Pd;

[2]

- (d) (i) $\text{CH}_3\text{CH}_2\text{Br} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{OH} + \text{Br}^-$;
 $\text{CH}_3\text{CH}_2\text{Br} + \text{OH}^- \rightarrow \text{CH}_2=\text{CH}_2 + \text{H}_2\text{O} + \text{Br}^-$;
Accept KOH and KBr in the balanced equations

dilute KOH compared to concentrated KOH;
 aqueous KOH compared to ethanolic KOH;
 warm/40- 50 °C compared to hot/80-100 °C ;
Accept any two reaction conditions.

[4 max]



curly arrow from O to H;
 curly arrow from C-H to C-C;
 curly arrow showing Br leaving;
 products $\text{CH}_2=\text{CH}_2 + \text{Br}^- + \text{C}_2\text{H}_5\text{OH}/\text{H}_2\text{O}$;

[4]

- (iii) addition;

[1]